Alexis Reboul-Salze
Max-Planck Institute for Gravitational Physics

Dynamos in Neutron Star Remnants: importance of non-ideal effects

Magnetic fields and turbulence play an important role in binary neutron star mergers as they govern the angular momentum transport in the neutron star remnant, while a large-scale magnetic field can also lead to the production of a collimated relativistic outflow, which can be observed as a short gamma-ray burst.

Alan Tsz Lok Lam
Max Planck Institute for Gravitational Physics, Potsdam (AEI)

Black hole-accretion disk collision in general relativity: Axisymmetric simulations

We first present SACRA-2D, a new MPI and OpenMP parallelized, fully relativistic hydrodynamics (GRHD) code designed for dynamical spacetime under axial symmetry, utilizing the cartoon method with finite-volume shock-capturing schemes for hydrodynamics. Motivated by recent discoveries of X-ray quasi-periodic eruptions, we revisit the collision between a black hole and an accretion disk using the SACRA-2D code. Assuming they orbit a supermassive black hole in orthogonal paths, we conduct a general relativistic simulation of the collision, varying the relative velocity from 0.032c to 0.2c (where c is the speed of light), along with a variety of disk thicknesses and a realistic local density profile for the disk. Our findings indicate that the mass of the outflow matter from the disk is slightly less than anticipated. We also demonstrate that the properties of the outflow matter induced by the incoming and outgoing phases of the black hole collision differ significantly.

Milton Ruiz
University of Valencia

Thermal effects on inertial modes of long-lived binary neutron stars

Binary neutron star mergers are prime candidates for gravitational wave astronomy, offering key insights into the physical phenomena operating during the post-merger phase. We perform fully general relativistic simulations of binary neutron stars that merge and form a long-lived remnant with a lifetime > 140 ms. The stars are modeled using four different thermal equations of state, which cover a range from soft to stiff. Consistent with previous findings, we observe that all binary remnants develop convective instability by $\gtrsim 30$ ms, triggering the emergence of inertial modes with frequencies lower than those of the quadrupole modes. Through a convective stability analysis, we show that differential rotation and buoyancy give rise to sustained convective patterns in the fluid.

Nicolas Sanchis-Gual
University of Valencia

Dynamical bosonic stars and GWs

Bosonic stars are hypothetical exotic compact objects composed of ultralight bosonic particles, and they have been proposed as potential candidates for dark matter. In this talk, I will present recent advances in our understanding of their stability and dynamical formation. I will then discuss the merger dynamics of bosonic stars, the resulting gravitational wave signatures, and how future detections could provide insight into the existence and properties of these objects in our Universe.

Panagiotis Giannadakis
King's College London

Non-linear Stability of Flux Compactifications with Numerical Relativity

We study the stability of flux compactifications in $3+1+N$ dimensions, where the compact space is an N-sphere. By performing dimensional reduction and exploring the conditions under which the geometry can be described as a product of a 4-dimensional cosmological spacetime with an N-sphere of dynamical radius, we reduce the problem to $3+1$ Einstein gravity. In this framework, the radius of the sphere acts as a minimally coupled scalar field (radion) with a potential that admits a metastable minimum. We then study with our Numerical Relativity code `GRChombo` various scalar field configurations that exhibit large spatial inhomogeneities, considering potentials with either de Sitter or Minkowski minima. We find that, within the limits where this effective description remains valid, the scalar field in most cases stabilizes at the potential minimum, thereby stabilizing the compactification in most cases. We have also observed cases where domain walls form between patches of stabilized compactification and regions that decompactify, as well as cases where large wavelength inhomogeneities can lead to black hole formation.

Nils Vu
Caltech

Solving the gravitational self-force problem with numerical relativity methods

For the upcoming space-based gravitational-wave detector LISA we will need to simulate binary black holes with extreme mass ratios (EMRIs). Because EMRI simulations are intractable with conventional numerical relativity methods, we turn to gravitational self-force methods to achieve these simulations. In this talk I present an approach that uses numerical relativity technology and the next-generation NR code SpECTRE to solve the gravitational self-force problem computationally. I demonstrate how we use discontinuous Galerkin methods, adaptive mesh-refinement, and the iterative elliptic solver algorithms developed for binary black hole initial data problems to solve for the self-force acting on a scalar charge in Kerr spacetime, and present progress towards solving the gravitational self-force problem with this technology.

Steve Liebling
LIU

Compact Object Mergers with MHDuet

We perform numerical relativity simulations of black hole-neutron star mergers with a fixed mass ratio of q=3, varying the BH spin to produce a wide range of post-merger accretion disk masses. The dimensionless magnetic flux on the BH evolves similarly across nearly two orders of magnitude in disk mass with implications for gamma ray bursts. We also are readying a new release of our open source code, MHDuet, for both CPUs and GPUs with new tests and scaling results.

Llibert Aresté Saló
KU Leuven

Binary Neutron Stars in scalar-Gauss-Bonnet gravity

We present the first numerical simulations of binary neutron star mergers in scalar–Gauss–Bonnet gravity performed in the modified puncture gauge. Implemented within the MHDuet code, our modified formulation enables stable evolution through merger and post-merger phases. These results open the door to systematic studies of scalar-Gauss-Bonnet effects on the gravitational wave signal and remnant dynamics in this class of modified gravity theories.

Inês Rainho
Universitat de València

Electromagnetic signatures from spin-misaligned black hole binaries in circumbinary disks

Numerical relativity plays a crucial role in modeling compact binary mergers and interpreting gravitational wave signals. We present a systematic study based on general relativistic magneto-hydrodynamic (GRMHD) simulations of circumbinary disks around tilted, unequal-mass binary black holes. We investigate how spin orientation influences jet and twin-jet structures during the premerger phase. Preliminary results suggest sudden changes in the outgoing Poynting luminosity around the time of merger, providing potential electromagnetic signatures of black hole mergers in active galactic nuclei. Such signatures could offer new insights into black hole growth mechanisms, the co-evolution of black holes and their host galaxies, and may contribute to explaining the formation of X-shaped radio galaxies.

Matthew Elley
University of the Basque Country

Primordial black hole formation from domain wall collapse

A variety of theories beyond the Standard Model predict the existence of topological defects such as domain walls in the early universe. Given certain conditions, it is possible for enclosed domain wall configurations to collapse to primordial black holes, which may contribute to some if not all of the estimated dark matter abundance. However, there are a number of uncertainties regarding the likelihood of black hole formation. One such uncertainty is the degree by which deformations of the domain walls hinder black hole production. By simulating the entire collapse of deformed domain wall configurations using numerical relativity, we attempt to alleviate this uncertainty.

Areef Waeming
Queen Mary University of London

Oscillon Formation in Modified Gravity

Formed in the early universe, oscillons are solitonic objects that may seed primordial black holes and leave imprints in the form of a gravitational wave background. I will describe work using non-linear relativistic simulations that include gravitational backreaction to study oscillons forming in a preheating phase of the post-inflationary universe. In particular, we study whether their compactness can reach levels sufficient to form black holes from generic initial perturbations. I will also show how modifications to gravity, inspired by the effective field theory approach, may change the dynamical strong field evolution.

Fernando Abalos
Universitat de les Illes Balears

Gauge fixing and strong hyperbolicity in second-order gravity theories

Physical theories described by partial differential equations (PDEs) require a well-posed initial value formulation to ensure predictability. We focus on strongly hyperbolic theories, a subclass within the well-posed family, for which Kreiss developed methods to test strong hyperbolicity in first-order PDEs. However, applying these techniques to second-order PDEs requires introducing many auxiliary variables, significantly complicating and extending the analysis. We present a method to simplify this process using matrix pencils and apply it to Gravitational Theories. Furthermore, for the latter, we introduce a new general family of gauge fixings and extensions that yield strongly hyperbolic formulations. This family reduces, for particular choices, to several popular gauges, such as the Bona-Massó, Gamma-Driver, Harmonic, and modified Harmonic gauges.

Jamie Bamber
University of Illinois Urbana-Champaign

Evolution of a black hole cluster in full general relativity

We evolve for the first time in full general relativity a small, collisional N-body black hole cluster of arbitrary total mass M. The bound cluster is initially compact (radius R/M $\approx$10), stable, and consists of 25 equal-mass, nonspinning black holes. The dynamical interactions of compact objects in N-body clusters is of great interest for the formation of black holes in the upper mass gap as well as intermediate and supermassive black holes. These are potential sources of gravitational waves that may be detected by both current and future observatories. Unlike previous N-body Newtonian and post-Newtonian simulations, no “subgrid physics” is required to handle collisions and mergers. We can therefore confirm in full general relativity several predictions from these simulations and analytic estimates: the runaway growth of a large black hole via repeated mergers; spindown of the central black hole with increasing captures; the ejection of a black hole with a large asymptotic velocity due to a several-body interaction; and a regime where mergers occur primarily via direct collisions on highly eccentric orbits instead of quasicircular inspirals. We extract the gravitational wave signal and find it has several distinct features associated with the compact cluster regime. Our results suggest the signal is sufficiently loud that next generation observatories would likely be able to detect similar events across most of the observable universe. This work is a preliminary proof-of-principle study that we hope will open up a new arena for numerical relativity and the study of N-body compact systems.

Anna Neuweiler
University of Potsdam

Divergence-Free Constraint Treatment in General-Relativistic Magneto-Hydrodynamic Simulations

Magnetic fields have a significant impact on the dynamics of binary neutron star mergers, particularly after the merger. Therefore, their inclusion is crucial for realistic simulations. We have recently extended our numerical-relativity code `BAM` to enable general relativistic magneto-hydrodynamic simulations employing hyperbolic divergence-cleaning. In this work, we compare our new implementation with other codes, including `SPRITZ`, `GRaM-X`, and `SACRA`, which employ different schemes for the evolution of magnetic fields and for satisfying the divergence-free constraint. Overall, our implementation shows good performance in the performed standard special-relativistic tests. Furthermore, we find good agreement in simulation results between `BAM` and `SACRA` for binary neutron star merger.

Swapnil Shankar
University of Tennessee Knoxville, Hamburg Observatory

3D full-GR simulations of magnetorotational core-collapse supernovae on GPUs: A systematic study of rotation rates and magnetic fields

We present a series of fully three-dimensional, dynamical-spacetime general relativistic magneto-hydrodynamics (GRMHD) simulations of core-collapse supernovae (CCSNe) for a progenitor of zero-age-main-sequence (ZAMS) mass $25M\odot$. We simulate a total of 12 models for simulation times in the range 190-260 ms to systematically study the effect of rotation rates and magnetic fields on jet formation via the magnetorotational mechanism. We have performed simulations on OLCF's Frontier using the new GPU-accelerated dynamical-spacetime GRMHD code GRaM-X for magnetic fields $B0 = (1e11, 1e12)G$ and rotation rates $\Omega0 = (0.14, 0.5, 1.0, 1.5, 2.0, 2.5)$ rad/s. We always resolve the entire region containing the shock with a resolution of at least 1.48 km. We find that models with $B0 = 1e11G$ fail to explode, while those with $B0 = 1e12G$ show a wide range of jet morphologies and explosive outcomes depending on the rotation rate. Models with $B0 = 1e12G$ and $\Omega0 = (1.0, 1.5)$ rad/s form jets that bend sideways, giving the ejecta a more spherical character, and possibly representing explosions that appear neutrino-driven even though they are magnetorotationally-driven. Models with $B0 = 1e12G$ and $\Omega0 \geqslant 2.0$ rad/s show ejecta velocities $\geqslant$ 15000 km/s, making them suitable candidates for broad-lined type Ic supernova progenitors. This work represents the largest set of 3D general-relativistic GRMHD simulations studying magnetorotational supernovae in full GR and demonstrates the potential of systematic studies with GPU-accelerated 3D simulations of CCSNe.

Oliver Markwell
Max Planck Institute for Gravitational Physics

Bridging the gap between Numerical Relativity and Gravitational Self Force

The detection of gravitational waves from intermediate mass-ratio binary black hole systems is an important science objective for the LISA mission. However, the modelling of late inspiral waveforms for these systems is chal- lenging. The mass-ratio is sufficiently extreme that the computational cost of numerical relativity simulations is unfeasibly high, however not extreme enough for gravitational self force to be necessarily accurate. Using the Spec- tral Einstein Code (SpEC), a multidomain spectral code, we simulate short sections of the inspiral for systems with mass-ratios as high as $1 : 32$, and initial orbital frequencies of $0.01/M$. This is higher in mass-ratio and sepa- ration than is common for numerical relativity, and allows us to extract the phase evolution, energy flux, and adiabacity in a region of parameter space not previously explored numerically. We can then extract the terms in the GSF expansion for these quantities. This allows us to evaluate the accuracy of the GSF expressions, and determine if higher order terms become relevant in the intermediate mass-ratio regime.

Aaron Held
École Normale Supérieure

Time evolution in the presence of ghosts: From toy models to black-hole binaries

I will clarify that opposite-sign kinetic terms are no obstruction for long-lived classical motion. For point-particle models, integrability allows for proof of global stability. For simple scalar field theories in (1+1) dimensions, numerical evolution demonstrates that (i) even the unquenched classical instability is not instantaneous, (ii) higher frequency modes are more stable not less stable, and (iii) heavy ghosts can effectively be integrated out. Finally, I connect these insights to recent progress in numerical relativity, enabling well-posed time evolution in higher-derivative effective field theories of gravity.

Luciano Rezzolla
Institute for Theoretical Physics, Frankfurt, Germany

Binary Neutron Stars: from macroscopic collisions to microphysics and astrophysics

I will discuss the rapid recent progress made in modelling these systems in Frankfurt. I will first discuss how the gravitational-wave signal can provide tight constraints on the equation of state, sound speed, and the occurrence of phase transitions. I will then illustrate the role that neutrinos have on the launching of collimated outflows from the post-merger remnant and on the ability of matching the GRB phenomenology. Finally, I will discuss a novel and tight correlation between the ratio of the energy and angular-momentum losses in the late-time portion of the post-merger signal, i.e., the ”long ringdown”, and the properties of the EOS at the highest pressures and densities in neutron-star cores.

Alejandra Gonzalez
Universitat de les Illes Balears

Black-hole – neutron-star mergers: new numerical-relativity simulations and multipolar effective-one-body model with spin precession and eccentricity

In this work, we produced numerical relativity (NR) simulations for different black hole - neutron star configurations around the tidal disruption regime to inform a ringdown waveform model within the effective-one-body (EOB) framework of TEOBResumS-Dali. We inspect the new data by studying the amplitude multipolar hierarchy of the extracted waveforms, the measured kick velocity due to gravitational waves, and present an updated remnant black hole model. The new EOB model improves the amplitude at merger by an order of magnitude and is the first waveform model including higher modes specific fits for mixed binaries. The model is validated with a new 12 orbit precessing configuration obtaining mismatches below 0.05 for low inclinations. All the NR data produced in this work is publicly released within the CoRe database.

Edoardo Giangrandi
University of Coimbra, University of Potsdam

Numerical Relativity Simulations of Dark Matter Admixed Binary Neutron Stars

Binary neutron star mergers provide insight into strong-field gravity and the properties of ultra-dense nuclear matter. These events offer the potential to search for signatures of physics beyond the standard model, including dark matter. We present the first numerical-relativity simulations of binary neutron star mergers admixed with dark matter, based on constraint-solved initial data. Modeling dark matter as a non-interacting fermionic gas, we investigate the impact of varying dark matter fractions and particle masses on the merger dynamics, ejecta mass, post-merger remnant properties, and the emitted gravitational waves. Our simulations suggest that the dark matter morphology - a dense core or a diluted halo - may alter the merger outcome. Scenarios with a dark matter core tend to exhibit a higher probability of prompt collapse, while those with a dark matter halo develop a common envelope, embedding the whole binary. Furthermore, gravitational wave signals from mergers with dark matter halo configurations exhibit significant deviations from standard models when the tidal deformability is calculated in a two-fluid framework. This highlights the need for refined models in calculating the tidal deformability when considering mergers with extended dark matter structures. These initial results provide a basis for further exploration of dark matter's role in binary neutron star mergers and their associated gravitational wave emission and can serve as a benchmark for future observations from advanced detectors and multi-messenger astrophysics.

Alex Vano-Vinuales
IAC3, University of the Balearic Islands

Hyperboloidal highway to the frontier at future null infinity

Gravitational wave radiation is only unambiguously defined at future null infinity – the "location" where light rays arrive and where global properties of spacetimes can be measured. Reaching future null infinity is thus crucial for extracting correct waveforms from numerical relativity simulations. Hyperboloidal slices extend to null infinity while being spacelike and smooth everywhere. Among the current efforts to the hyperboloidal method, I will focus on free evolution of the conformally compactified BSSN / Z4 equations. I will illustrate several relevant aspects of the approach in spherical symmetry, and update on the ongoing efforts towards hyperboloidal simulations in full 3D.

Hannes Rüter
CENTRA, Instituto Superior Técnico, Universidade de Lisboa

A kinetic theory model for relativistic stars

I present a model to evolve spherical stars within full kinetic theory by solving the relativistic Vlasov-Boltzmann equation coupled to the Einstein field equations. The Vlasov-Boltzmann equation allows to fully consistently model matter out of thermal equilibrium, overcoming the restrictions of ideal and near-ideal fluid models typically used for neutron stars. I will discuss the spectral discretisation method that helps to cope with the six-dimensional phase space of the Vlasov-Boltzmann equation. Furthermore I will present some physical results that are enabled by the model.

Federico Schianchi
University of the Balearic Islands

Implementation of Radiation Transport in Neutron Star Mergers Using High-Order IMEX Schemes

The detection of the blue kilonova AT2017gfo and the short gamma-ray burst GRB170817A, associated with the same binary neutron star merger that generated the gravitational wave signal GW170817, heralded a new era in the field of multi-messenger astrophysics. But together with this wealth of new data came the need for more accurate and detailed models. On one hand, during the last orbits of the inspiral, gravity and velocities are too strong to allow for valid approximations, and the full Einstein Field Equations have to be solved numerically. On the other hand, the extreme density of neutron stars requires a detailed modeling of both strong and weak nuclear interactions. Numerical-relativisty codes have proven, in the last decade, to handle the gravitational interaction very accurately, giving a great contribution to the modeling of gravitational waveforms emitted by compact binary mergers. However, their microphysical description remained poorer, leading to uncertainties in the modeling of electromagnetic counterparts and r-process nucleosynthesis estimates, highlighting the importance of implementing advanced methods. In particular, modeling neutrino interactions has became a popular topic in the binary neutron star merger community. This talk provides an outline of the recent developments in the BAM and MHDueT codes to include weak nuclear interactions, with a particular focus on the implementation of a first-order multipolar radiation transport (M1). Such method is the state of the art in binary neutron star merger simulations, offering a good balance between computational costs and accuracy. However, it exhibits significant computational challenges due to the stiff coupling between fluid and radiation, and leaves a wide scope of improvement of its accuracy and physical consistency.

William Cook
Friedrich-Schiller University Jena

Turbulence in Magnetised Neutron Stars

The magnetic field configuration in the interior of Neutron Stars is an open problem and may be impacted by the influence of a turbulent cascade within the star. Assessing the impact of turbulent flow with numerical simulations requires incredibly high resolution as well as long lived simulations covering multiple Alfven times. We present a series of high resolution simulations of magnetised isolated neutron stars lasting at their longest 1.2s, to assess this issue; the longest lasting and highest resolution such simulations to date. We discuss the impact of the magnetic field on the turbulent flow in the star interior, finding a turbulent cascade driven by the magnetic field dynamics, as well its effect deforming the star itself. We also investigate the long term evolution of the magnetic field configuration itself, and the associated helicity of the late time configuration.

Yi Qiu
Penn State University

Neutrino Flavor Conversion in Neutron Star Merger Simulations

Gravitational waves (GWs) and electromagnetic (EM) radiation from colliding binary neutron stars (BNS) contain valuable information about the nature of neutron stars and the astrophysical processes that produce heavy elements. With the advent of next-generation multi-messenger detectors, it becomes crucial to pair these observations with precise models of merger dynamics, which can only be achieved through ab-initio supercomputer simulations. Currently, BNS simulations suffer from significant systematic errors due to the classical treatment of neutrinos. We present the first numerical relativity simulations including neutrino flavor transformations in BNS mergers. We find that neutrino flavor conversions impact the composition and structure of the remnant, potentially leaving an imprint on the post-merger gravitational-wave signal. They also have a significant impact on the composition and nucleosynthesis yields of the ejecta.

Miquel Miravet-Tenés
University of Southampton

Sub-grid modelling of MRI-driven turbulence in magnetised, differentially rotating neutron stars

In the aftermath of a binary neutron star merger, the resulting remnant can be a differentially rotating, magnetised hypermassive neutron star. Under these conditions, the remnant is susceptible to the magnetorotational instability (MRI), which triggers magnetohydrodynamic turbulence that significantly influences the star's large-scale dynamics. One key consequence of this turbulence is the outward transport of angular momentum, which directly affects the remnant's stability and lifetime. However, most current numerical simulations of binary neutron star mergers are unable to resolve the MRI due to its inherently small wavelength. To address this limitation, sub-grid models have been proposed to capture the effects of unresolved small-scale physics in terms of large-scale quantities. In this talk, I will introduce the first implementation of the MHD-Instability-Induced Turbulence (MInIT) model in global Newtonian simulations of a differentially rotating, magnetised neutron star prone to the MRI. I will demonstrate that this model successfully reproduces the angular momentum transport driven by small-scale turbulence.

Daniela Doneva
University of Tübingen

Black hole mergers in scalar-Gauss-Bonnet gravity: unequal mass ratio and dynamical scalar field growth

Scalar-Gauss-Bonnet gravity offers an important playground for exploring possible deviations from GR during black hole mergers. Even though significant progress has been made in the direction of model-independent tests of gravity, a complete understanding of the various beyond-GR effects in the observed waveforms is important to be performed at least in a handful of alternative theories. In the present talk, we will discuss the advances in this direction, focusing on black hole binaries with unequal mass ratios, following the evolution through the inspiral, the merger, and the ringdown. The possibility of dynamical scalar field development as the two black holes approach each other will also be discussed.

Marcelo Salgado
Instituto de Ciencias Nucleares, UNAM (Mexico) and UIB

Current developments about rotating hairy black holes and clouds

I summarize some of the (numerical) results concerning rotating black holes endowed with complex-valued scalar hair (RHBH) and their respective cloud counterparts. In particular, I will review the (linear) stability analysis of the RHBH and possible routes of development.

Frederik De Ceuster, Tom Colemont
Leuven Gravity Institue, KU Leuven

Probabilistic Numerical Relativity: Solving Einstein's equations as a Bayesian regression problem

Gravitational waves (GWs) provide a unique probe for some of the most extreme astrophysical phenomena. However, to leverage the full potential of next-generation gravitational wave observatories, such as the Einstein Telescope (in Europe) and LISA (in space), we will need to improve the efficiency of numerical relativity (NR) simulations in terms of computational speed and accuracy. In this talk, we will introduce probabilistic numerics (PN) as a promising new approach to gain control over uncertainties in NR, and we will demonstrate ways to leverage this control and optimise simulations. Instead of creating a model with specific parameters, the idea of PN is to model the probability distribution over a region of parameter space. At first, this might seem impractical or even impossible, but it turns out that many (classical) numerical methods with only minor alterations can already achieve this. While the mean of the probability distribution then corresponds to the classical result, its width can be used to model the uncertainty on that result. This can include uncertainty on the input parameters as well as uncertainties intrinsic to the numerical method, for instance, due to discretisation. Control over these uncertainties can be very powerful, since it can reveal where more or less approximation is warranted. Furthermore, in addition to the causal structure of spacetime, PN also provides access to the correlation structure, which can help understanding. We will provide a first demonstration of this approach with a PN solver for the Einstein equations, assuming a conformally flat condition (CFC).

Arthur Offermans
KU Leuven

A general-relativistic full Boltzmann solver

Simulations of astrophysical systems where neutrinos play a significant role, like core-collapse supernovae, would ideally solve the neutrino transport equation fully, i.e. solve the full Boltzmann equation. Because of its very high computational cost (6+1D), simulations generally rely on approximations of the equation that are more affordable. It is however difficult to estimate what is lost through these approximations if we do not have access to a full solution. Therefore, we developed a multidimensional full Boltzmann solver based on the Finite Volume method within the GRMHD simulation code Gmunu in order to perform those more accurate simulations. In this presentation, we present our solver and its performance on some first test cases. We also discuss the main challenges of solving this 7D equation, both in terms of computational cost and accuracy.

Philipp Moesta
University of Amsterdam

3D GRMHD Simulations of Black Hole Formation in Core-Collapse Supernovae

We present the first three-dimensional, fully general-relativistic magnetohydrodynamic (GRMHD) simulations of black hole (BH) formation in the gravitational collapse of a stellar core. The ability to follow stellar core-collapse through to the final compact remnant in 3D is crucial for modeling natal BH properties (including masses, spins, and kicks) and predicting gravitational wave (GW) signatures of core-collapse events. However, such simulations have long remained elusive in GRMHD due to severe computational challenges. We use the GPU-accelerated dynamical spacetime GRMHD code GRaM-X with a microphysical tabulated equation of state to follow the collapse, core-bounce, shock propagation, and eventual BH formation of a massive stellar progenitor. We present simulations for a star with a zero-age-main-sequence mass of 45 $M\odot$, moderate rotation (consistent with expectations from stellar evolution modeling), and different magnetic field configurations

Boris Daszuta
Friedrich-Schiller-Universität

GR-Athena++: general-relativistic moment-based radiation magneto-hydrodynamics

In description of astrophysical scenarios such as core-collapse supernovae it is well-known that accurate modelling of neutrino transport can play a crucial role in simulation quality. In this talk, we utilize the truncated-moment formalism so as to reduce the Boltzmann equation to a more computationally tractable form. Here only the first two moments are retained (M1 scheme) and we work within the grey approximation. This we incorporate within the GR-Athena++ framework which allows for exploiting the extant general-relativistic magneto-hydrodynamical (GRMHD) infrastructure we have previously developed. The robustness of our M1 implementation is verified over a set of benchmark problems, which constitute a stringent set of tests. Following this GRMHD+M1 applications are discussed.

Anna Heffernan
University of Balearic Islands

Eccentricity Reduction for High-Mass Ratio Compact Binaries

Gravitational wave astronomy requires precision waveform models for accurate parameter estimation and the resulting science. Numerical relativity supplies a key ingredient to all present waveform models: accurate models of the inspiral, merger and ringdown. As current ground detectors become more sensitive and with future ground detectors as well as LISA approaching, the need for more coverage of the parameter space of compact binaries is becoming astute; in particular, higher mass ratio simulations. In this project, we examine the eccentricity reduction techniques required for the initial data of quasi-circular, high-mass ratio compact binaries. We compare both previously known techniques and newer variations to optimise the eccentricity reduction and lower the number of (expensive) simulations required.

Michael Müller
University of Greifswald

Amplification and coherent structure formation processes in the magnetic field evolution of long-lived remnants from binary neutron star mergers

We present new results from three-dimensional general-relativistic magnetohydrodynamic simulations of binary neutron star (BNS) mergers resulting in a long-lived remnant neutron star, employing a tabulated, composition-dependent, finite-temperature equation of state, a vector potential formalism for the magnetic field evolution and approximate neutrino transport. Considering an equal-mass BNS with $1.35M_{\odot}$ - constituents, the numerical evolution is performed without the assumption of symmetries and the focus of this study is on informing the discussion on processes involved in the post-merger magnetic field amplification and emergence of coherent field structures, as a follow-up to the simulations presented in Combi and Siegel 2023a,b. We demonstrate that the magnetorotational instability is well resolved outside the dense core of the remnant and study the interaction of the thusly induced turbulence at the disk-star interface with new diagnostics, in an attempt to ascertain the role of the star in the magnetic field evolution.

Aman Agarwal
University of Greifswald

Ignition of weak interactions and r-process outflows in massive collapsar accretion disks

The core collapse of rapidly rotating massive $\sim 10\,M_{\odot}$ stars ("collapsars") comprises a leading model for the central engines of long-duration gamma-ray bursts (GRBs), and represents a promising source of neutron-rich environments for r-process nucleosynthesis. Here, we explore collapsar accretion disk flows around black holes of mass $M = 3$–$3000\,M_{\odot}$ using long-term, three-dimensional general-relativistic magnetohydrodynamics (GRMHD) simulations with weak interactions. We follow the physical conditions of the accretion flow over viscous timescales as the disks transition through the "ignition" accretion rate ($\dot{M}_{\rm ign}$), above which weak interactions become energetically relevant and electron degeneracy leads to self-neutronization of the dissociated nucleon plasma. In good agreement with analytic α-viscosity ($\alpha_{\rm eff}$) accretion-disk models, we find this ignition threshold to scale as $\dot{M}_{\rm ign} \propto M^{4/3}\alpha_{\rm eff}^{5/3}$ up to black hole masses of

$M \sim 3000\,M_\odot$, beyond which ignition generally breaks down due to insufficient disk temperatures. We demonstrate that stellar models of very massive stars with masses ~ 250–$100{,}000\,M_\odot$ can give rise to black holes of mass $M \sim 30$–$1000\,M_\odot$ accreting at $\dot{M} \gtrsim \dot{M}_{\rm ign}$, yielding ~ 10–$100\,M_\odot$ of light and heavy r-process elements per event. Radioactive heating of the r-process disk wind ejecta may power an optical/infrared transient similar to kilonovae from neutron star mergers, but brighter and longer in duration ($\gtrsim 1$ month; "super-kilonovae"), potentially detectable by the *Roman Space Telescope*. Multiband gravitational waves in the ~ 0.1–50 Hz range from nonaxisymmetric instabilities in self-gravitating massive collapsar disks may be detectable by proposed third-generation observatories out to hundreds of Mpc. Such multi-messenger signatures from very massive collapsars may be used to probe Population III stars.

Maria Chiara de Simone
Rochester Institute of Technology

General Relativistic Magnetohydrodynamic Simulations of Circumbinary Disk Accretion onto Recoiling Supermassive Black Hole Binaries

Supermassive black holes (SMBHs) are observed at the center of almost all galaxies. Supermassive binary black holes (SMBBHs) mergers are expected to be the natural outcome of hierarchical growth and galaxy mergers, representing some of the most energetic phenomena in the Universe. Numerical simulations have shown that, in gas-rich galaxy mergers, a substantial amount of gas tends to accumulate in the center around the resulting SMBBH, leading to the expectation that such mergers will produce detectable electromagnetic (EM) counterparts. During merger, anisotropic emission of gravitational waves carries away linear momentum imparting a recoil or 'kick' on the merged hole. The magnitude and direction of this recoil are governed by the initial binary parameters, including spin orientations and mass ratios. We perform full 3D general relativistic magnetohydrodynamical (GRMHD) simulations to investigate the dynamics of accreting gas and the generation of EM signals in recoiling SMBBH mergers. We explore the "hang-up kick" configuration as well as unequal-mass binaries with varying spin configurations. The goal is to analyze how gravitational recoils influence the accretion environment and EM observability of these events. To achieve this, we initialize our GRMHD simulations using astrophysically realistic conditions derived from a long-term circumbinary disk (CBD) simulation which employs curvilinear coordinates and a post-Newtonian (PN) metric with a cutout excising the central region containing the binary. These data is then transferred via a refined "handoff" procedure into IllinoisGRMHD for full numerical evolution carried out through the merger and post-merger phase. We study the dependence of multiple diagnostics, including the mass accretion rate, the Poynting flux and the mass enclosed at different radii, on the spins of the black holes and their mass ratio. Additionally, we analyze the dynamics and structure of the minidisks surrounding each black hole and the evolution of the jets ejected by them.

Shunhui Yao
Queen Mary University of London

The Gregory-Laflamme Instability of Five-dimensional Black Strings in Lovelock Gravity

Einstein's general theory of relativity (GR) has been remarkably successful in describing gravitational phenomena. However, its predictive power breaks down in extreme regimes. In higher dimensional space time, a well-known example is the Gregory-Laflamme (GL) instability of black strings, where the nonlinear evolution leads to horizon fragmentation and ultimately to the formation of a naked singularity—a clear violation of weak cosmic censorship conjecture. Near the pinch-off of the black string , where the curvature becomes large, higher-derivative corrections to GR are expected to become significant. In five-dimensional spacetimes, the Gauss-Bonnet term provides the leading nontrivial correction to GR, making Lovelock gravity, specifically Einstein-Gauss-Bonnet theory a natural setting to explore potential resolutions to the singularity. In this talk, I will present recent numerical simulations of the GL instability in Lovelock gravity under a well-posed formulation, with the GRChombo code adapted for higher-dimensional numerical relativity. These simulations offer new insights into how higher-curvature corrections could influence the nonlinear dynamics and alter the ultimate fate of the instability.

Tomáš Ledvinka
Charles University, Faculty of Mathematics and Physiscs

Near-critical spacetimes of axisymmetric gravitational wave collapse

In general relativity, various fields, and also matter models, exhibit so-called critical collapse, an interesting behavior observed when the initial field state leading to the gravitational collapse is fine-tuned between black hole formation and field dispersal. The critical gravitational collapse has been extensively studied in spherical symmetry; nevertheless, the interesting situation where the black hole is formed by purely vacuum collapse of gravitational waves cannot happen in spherical symmetry. For these purely vacuum spacetimes, the interpretation must be based on geometric quantities. Their analysis shows that such spacetimes differ significantly from their spherically symmetric critical collapse counterparts. In the talk, I will briefly mention methods that allowed, after many years, the numerical construction of near-critical spacetimes of collapsing axisymmetric gravitational waves. In the largest part of the talk, I will discuss properties of these spacetimes, how they behave when approaching critical initial data, and which aspects of universality have been identified so far for gravitational wave critical collapse. This talk is based on joint work with A. Khirnov.

Sophia C. Schnauck
Max Planck Institute for Astrophysics

Gravitational waves from 3D GRMHD simulations of magnetorotational core-collapse supernovae

With the rise of gravitational wave detections and future detectors such as the Einstein Telescope, detailed source modelling is essential. Core-Collapse Supernovae (CCSNe) are promising targets, enabling us to probe for information from the stellar interior during collapse and the subsequent explosion. We investigate the gravitational wave signals from core-collapse supernovae for ten progenitor stars through some of the first production-level GPU-based simulations, using the GPU-accelerated dynamical-spacetime general relativistic magnetohydrodynamics code GRaM-X. We consider two $25M\odot$ and eight $35M\odot$ models in full 3D and examine a range of rotation rates between 0.0 and 3.5 rad/s with an initial seed magnetic field of 10^{12} or 10^{13}G. Our ten model analysis allows for a comprehensive initial investigation of the potential impacts of rotation, initial seed field, and progenitor mass/composition, as well as a display of the capabilities of the newly developed GRaM-X code. We find that models with a higher initial rotation generally display a more dynamical explosion and result in a more pronounced gravitational wave signal.

Kota Hayashi
Max Planck Institute for Gravitational Physics

Jet from binary neutron star merger with prompt black hole formation

We performed the first numerical-relativity neutrino-radiation magnetohydrodynamics simulation for a prompt-collapse binary neutron star merger to predict the multi-messenger signals from the foreseen event similar to GW190425. The simulation lasts 1.5 seconds after the merger, the longest among binary neutron star merger simulations that self-consistently solve from the inspiral stage. It revealed the large-scale magnetic field generation by an alpha-Omega dynamo in the black hole-accretion disk system formed after the merger. It also confirmed the launch of the collimated magnetically driven outflow from the prompt collapse case for the first time.

Rita Megale
Universita' della Calabria, Rende, Italy

Novel analysis technique for turbulence measurements near black holes

Turbulence in the vicinity of black holes represents a poorly understood, very complex challenge. In particular, black hole accretion disks are characterized by the accumulation of highly dynamic plasma in orbital motion. From what we see in M87* and Sgr A* from EHT Collaboration, the accreting plasma is unstable, chaotic and turbulent and the triggered instabilities are perturbative channels that can initiate magnetic reconnection. Therefore, it is crucial to measure the presence of an active turbulence cascade and to quantify the properties of turbulence, even close to the black holes, where the spacetime is significantly distorted. We propose a novel analysis technique for the comprehension of turbulence in extreme gravitational fields, such as the ergosphere of compact objects. Specifically, we develop a turbulence measurement that, in principle, can be valid in any curved spacetime and in a fully covariant formalism, taking into account the local spatial metric of Kerr-type black holes, we define a Proper Length Spectrum (PLS). We demonstrate that the new technique, based on the computation of structure functions on generic manifolds, can correctly capture the scaling laws indicative of an inertial range cascade. By applying the PLS to the turbulent density field coming from simulations of the Black Hole Accretion Code (BHAC), we estimate the scaling laws of turbulence in the disk, the wind, and the near-horizon regions.

Guillermo Lara
Max Planck Institute for Gravitational Physics (Albert Einstein Institute)

Simulating scalarized black hole binaries in spectre

In this talk, I will present recent developments aimed at simulating black hole binaries beyond general relativity in spectre, an open-source numerical relativity code by the SXS Collaboration. For concreteness, I focus on the case of scalar Gauss-Bonnet gravity. I will describe progress in constructing initial data for scalarized binaries in equilibrium, as well as advancements in performing stable time evolution with the fixing-the-equations approach [Phys.Rev.D 96 (2017) 8, 084043].

Lik Hang Harry Shum
University of Nottingham

Simulating neutron stars with dissipative hydrodynamics

In this talk, I will discuss our work in modelling neutron stars using the recently developed formulation for relativistic dissipative hydrodynamics, known as the BDNK theory. By performing numerical simulations of neutron stars in spherically symmetric spacetimes, we will study how incorporating dissipation using the BDNK theory affects the physical predictions of the system.

Kyohei Kawaguchi
AEI

Monte Carlo-based neutrino-radiation hydrodynamics simulations for pair annihilation driven jets from black-hole torus systems

Neutrino-antineutrino pair annihilation has been proposed as a possible mechanism for launching relativistic jets in black hole (BH) or neutron star (NS) torus systems. However, self-consistent studies of this process remain limited due to the complexity of radiative transport and weak interaction cross sections. In this talk, I will present our recent axisymmetric general relativistic viscous hydrodynamics simulations of BH torus systems, incorporating Monte Carlo-based full Boltzmann neutrino transport, to investigate the role of neutrino pair annihilation in driving relativistic outflows. Our models cover a wide range of BH spins, torus masses, and viscosity parameters. We find that pair annihilation leads to the formation of relativistic fireballs in most cases, except for those with low spin and high viscosity. The isotropic equivalent energies of these outflows reach 10^{51} erg with durations ¡ 0.2 s. While this is insufficient to explain the brightest short gamma-ray bursts (sGRBs), our results suggest that pair annihilation may account for some low luminosity sGRBs and GRB precursors. We also provide updated scaling relations for the annihilation energy deposition rate as a function of the accretion rate, which are broadly consistent with the previous studies.

Henrique Gieg
University of Potsdam

On the Role of Muons in BNS Merger Simulations

In this work we present a first set of BNS merger simulations including muons and antimuons in the EoS. Muonic charged-current reactions are considered within the elastic approximation for computation of opacities, and neutrino transport is included via neutrinos leakage scheme. We found that the inclusion of muons may result in additional stabilization of the remnant via enhanced rotational support after a stronger centrifugal bounce. Composition-wise, de-muonization dominates the post-merger evolution, and follows from beta-equilibration of cooled and decompressed material, while the bulk of muons come from the cold, fusing NS cores, mainly found in high-density regions. Finally, the amount of ejecta is reduced for the muonic runs due to additional energy loss by emission of muon-flavored neutrinos.

Thomas Celora
Institute of Space Sciences (ICE-CSIC)

Impact of magnetic field gradients on the development of the MRI in binary neutron star mergers

The magneto-rotational instability (MRI) is a cornerstone of accretion disk theory, and it is often invoked to explain the generation of large-scale, poloidal magnetic fields in binary neutron star mergers. However, simulations that begin with weak seed fields and follow their amplification to saturation lack convincing evidence of MRI activity, casting doubts on its role in this setting. In this talk, I will discuss how the classical MRI extends under more realistic post-merger conditions, where magnetic fields present complex topologies and field gradients are significant. In particular, I will present modified expressions for the timescale and wavelength of the fastest growing mode, along with a generalised instability criterion that captures the influence of magnetic field inhomogeneities. Finally, I will show the results of applying the extended MRI to a high-resolution simulation of a long-lived merger remnant. Our results indicate that the MRI is significantly hindered in the early post-merger phase, with favourable conditions—where the instability condition is met and the growth rate is sufficiently fast—emerging only at later stages, of the order of 100 milliseconds after merger.

Harry Ho-Yin NG
Goethe University Frankfurt

Accurate muonic interactions in neutron-star mergers and impact on heavy-element nucleosynthesis

The abundances resulting from r-process nucleosynthesis as predicted by simulations of binary neutron-star (BNS) mergers remain an open question as the current state-of-the-art is still restricted to three-species neutrino transport. We present the first BNS merger simulations employing a moment-based general-relativistic neutrino transport with five neutrino species, thus including (anti)muons and advanced muonic β-processes, and contrast them with traditional three neutrino-species simulations. Our results show that a muonic trapped-neutrino equilibrium is established, forming a different trapped-neutrino hierarchy akin to the electronic equilibrium. The formation of (anti)muons and the muonization via muonic β-processes enhance neutrino luminosity, leading to a stronger cooling in the early post-merger phase. Since muonic processes redirect part of the energy otherwise used for protonization by electronic processes, they yield a cooler remnant and disk, together with neutrino-driven winds that are more neutron-rich. Importantly, the unbound ejected mass is smaller than in three-species simulations and, because of its comparatively smaller temperature and proton fraction, it can enhance lanthanide production and reduce the overproduction of light r-process elements for softer equations of state. This finding underlines the importance of muonic interactions and five neutrino species in long-lived BNS remnants.

Olindo Zanotti
University of Trento

A first–order BSSNOK formulation of the Einstein equations for numerical relativity

I will present a first order (in space and time derivatives) formulation of the BSSNOK Einstein–Euler equations that is strongly hyperbolic and it allows for the implementation of a single high order numerical scheme for its solution. A comparison will be shown among different numerical schemes such as Central WENO finite differences and Discontinuous Galerkin schemes, with important applications to the merger of binary astrophysical sources.

Rohan Srikanth
University of Potsdam

Scalar field dark matter around binary neutron star mergers simulations

Binary Neutron Star mergers provide a powerful laboratory for testing fundamental physics through gravitational-wave observations. In this study, we explore the dynamics of a complex scalar field surrounding binary neutron star system, modeling scenarios motivated by dark matter phenomenology. We investigate how the scalar field evolves throughout the inspiral, merger, and post-merger phases, focusing on its interaction with the binary, for different scalar field parameters. We aim to provide insights into possible scalar field signatures in gravitational wave signals by investigating the dephasing and the post-merger remnant focusing on ejecta and electromagnetic counterparts.

Mario Imbrogno
Department of Physics, University of Calabria (Italy)

Multi-scale Turbulence in Astrophysical Plasmas Near Black Holes

Turbulence near black holes, where extreme gravity couples with plasma interactions to produce highly complex dynamics, remains a major open problem in astrophysics. In this work, we present a cross-scale investigation of plasma turbulence, bridging macroscopic and microscopic kinetic regimes. From a macroscopic (fluid) perspective, we develop a covariant framework for turbulence diagnostics based on structure functions defined on generic manifolds. Applying this to data from simulations with the Black Hole Accretion Code (BHAC), we define a power spectrum of fluctuations in a magnetized accretion disk and identify an inertial-range cascade consistent with hydrodynamic-like turbulence. At the microscopic (kinetic) scale, we explore turbulence in fully kinetic plasmas using high-resolution relativistic particle-in-cell (PIC) simulations. These simulations reveal long-lived, magnetically dominated vortices with force-free profiles. We model these meta-stable equilibria using a self-consistent kinetic theory inspired by the Harris pinch, showing that their structure is well approximated by a Gold–Hoyle solution in cylindrical coordinates. Turbulence evolves through vortex interactions, generating new meta-stable states in a self-similar cascade. This mechanism has potential implications for plasmoid formation near compact objects and the emergence of coherent structures in space plasmas. Finally, we investigate the role of plasma composition via PIC simulations of relativistic multi-species plasmas composed of electrons, protons, and positrons. Turbulence in these systems drives magnetic reconnection, forming current sheets and magnetic islands. We find that increasing positron concentration reduces reconnection efficiency, regulated by the electric field arising from the divergence of the electron and positron pressure tensors. Overall, our findings provide new insights into energy dissipation and particle acceleration in turbulent plasmas near compact objects, highlighting the critical role of multi-species interactions in high-energy astrophysics.

Geoffrey Lovelace
California State University, Fullerton

Simulating binary black holes with SpECTRE

In the next decade, a new generation of observatories on Earth and in space will observe gravitational waves from binary black holes with unprecedented sensitivity. Interpreting these observations will require models of the gravitational waveforms much more accurate than today's state of the art. Because these models require numerical relativity near the time of merger, numerical-relativity simulations of binary black holes will also need to be significantly more accurate. SpECTRE is a next-generation, open-source numerical-relativity code that aims to achieve the accuracy future observatories will need by combining a discontinuous Galerkin method with task-based parallelism. In this talk, I will present recent results using SpECTRE to simulate binary black holes through inspiral, merger, and ringdown, including accuracy of the calculated waveforms. I will also discuss future plans toward readying SpECTRE for producing waveforms at the accuracy future detectors will need.

Isabel Cordero-Carrión
University of Valencia (Spain)

Reformulation of Einstein equations in the Fully Constrained Formulation: local uniqueness, post-Newtonian expansion and initial data

Einstein equations can be written in the so-called Fully Constrained Formulation (FCF). This formulation has two different sectors: the elliptic sector, formed by the Hamiltonian and Momentum constraints together with the equations derived from the gauge choice; and the hyperbolic sector, formed by the evolution of the rest of the spacetime metric variables, which encodes the gravitational radiation. In this work, we present a modification of both sectors that keeps local uniqueness properties of the elliptic system of equations and includes a hierarchical post-Newtonian structure of all the elliptic and hyperbolic equations. This reformulation can have potential applications in cosmology and relativistic astrophysics. Moreover, we show how initial stationary data can be computed numerically using this formulation without assuming a conformally flat spatial metric, with the illustrative example of a rotating neutron star.

Carsten Gundlach
University of Southampton

Numerical simulations of gravitational collapse on null cones with a regular centre

The use of null coordinates in numerical relativity has focused either on spherical symmetry (in particular, collapse and black hole interiors) or, with less symmetry, on situations where data are posed on an ingoing null cone, or a timelike inner boundary, as well as an outgoing null cone. By contrast, I present the first simulations of black hole formation from regular initial data posed on an outgoing null cone with a regular centre (vertex), constructing the spacetime on the full domain of dependence of these data. In particular, I present results on critical phenomena at the threshold of black hole formation for a scalar field coupled to gravity in axisymmetry. The coordinates can be adapted to critical collapse in order to make fine-tuning to the black hole threshold much cheaper than with a 3+1 code with adaptive mesh refinement. If there is time, I will also review different formulations and gauge choices within the null cone framework, and how they are related to each other and the existing literature.

Rahime Matur
University of Southampton

The Impact of Black Hole Spin on Black Hole–Neutron Star Mergers

The GW230529 event demonstrated that black hole–neutron star systems can contain low-mass black holes, making them particularly favourable for multimessenger observations. Such observations are crucial, as they allow us to extract more information from a single event. They carry direct imprints of the source objects, enabling constraints on key parameters such as spin magnitude and orientation. Most importantly, they provide essential insights into the equation of state of neutron stars. However, the role of black hole spin in these mergers is not well understood. In this talk, we present our latest numerical relativity simulation results, focusing on how black hole spin influences both the gravitational wave signal and the properties of the ejected matter. We further examine whether these effects can be detected and constrained with current and next-generation ground-based gravitational wave observatories.

Takami Kuroda
Max Planck Institute for Gravitational Physics

Diverse scenarios of massive stellar collapse

Massive stellar collapse and subsequent supernova (SN) explosion are governed by interplay of all four fundamental forces of nature. While recent progress in SN theory has rapidly deepened our understanding at relatively less massive progenitor side, where relativistic effects are somewhat minor and the Newtonian approximation is still applicable, more massive progenitor side with a highly relativistic compact star formation, like a black hole, has not been well studied because of the complexity of handling the neutrino transport (i.e. weak force) in highly curved spacetime. To venture into still poorly explored SN physics in full relativity regime, our unique SN code is based on numerical relativity coupled with a multi-energy neutrino transport, which enables us to seamlessly follow all relevant phases: massive stellar core collapse, nascent neutron star evolution, SN explosion, if happens, and beyond BH formation. In this talk we will introduce our latest results presenting various SN explosion scenarios covering from low- to high-mass end of SN progenitors and associated multi-messenger signals.

Ricard Aguilera Miret
Hamburg Universität

The robustness of magnetic field amplification in neutron star mergers

The first gravitational wave (GW) detection of a neutron star merger (GW170817) was accompanied by a firework of electromagnetic radiation. The complementarity of the received information allowed for a number of major leaps forward on many long-standing problems. It allowed, for example, to restrict the propagation speed of gravity to within 1 part in 10^{15} to the speed of light and therefore placed important constraints on alternative theories of gravity. By placing constraints on the tidal deformability of the neutron stars in the last inspiral stages these observations ruled out several dense matter equation of state. When two neutron stars merge, their dynamics are governed by physics under the most extreme conditions including strong spacetime curvature, ultra-high matter densities, luminous neutrino emission and the rapid amplification of the initial neutron star magnetic fields. These initial magnetic fields, although small, can be amplified by some orders of magnitude through various processes, such as the winding effect due to the large-scale differential rotation of the remnant, alpha-dynamo, the Kelvin-Helmholtz instability (KHI) and the magneto-rotational instability (MRI), among other instabilities. In the KHI phase, the magnetic field grows exponentially, meaning that perturbations of the shortest length scales that can be numerically resolved grow fast and even the highest resolved simulations to date are likely still far from completely resolving the instabilities associated with the MHD turbulence. In this presentation I will show convergent results regarding how sensitive the magnetic field evolution is to the initial topology of the magnetic field, the total mass of the merging binary, the mass ratio of its components, the stellar spins and the equation of state. I will show that strong and rapid amplification of the magnetic field to volume-averaged values of $\sim 10^{16}$ G in the high-density regions is a very robust outcome of a neutron star merger and this result is hardly impacted by either initial magnetic field strength and topology, mass, mass ratio, spin or equation of state.

Masaru Shibata
Max Planck Institute for Gravitational Physics

Self-consistent scenario for jet and stellar explosion in collapsar

A self-consistent scenario for jet and stellar explosion in collapsar, based on neutrino-radiation resistive magnetohydrodynamics simulations will be presented.

David Neilsen
Brigham Young University

Gravitational wave science with Dendro-GR

Third generation gravitational wave detectors will make detections with significantly improved precision, allowing them to also detect signals from new astrophysical sources. Computing waveforms with the same level of precision using numerical relativity is a significant computational challenge, which will require a combination of different computational approaches. Recent innovations in Dendro-GR have significantly improved its current and expected accuracy and efficiency, including constraint damping and new refinement and differencing strategies. This work indicates some promising approaches toward satisfying accuracy requirements for third-generation detectors.

Stephan Rosswog
Hamburg Observatory

Fast ejecta from neutron star mergers

The ejection of neutron-rich matter is one of the most important consequences of a neutron star merger. While the bulk of the matter is ejected at fast, but non-relativistic velocities (≈0.2c), a small amount of mildly relativistic dynamic ejecta have been seen in a number of numerical simulations. Such ejecta can have far-reaching observational consequences ranging from the shock breakout burst of gamma-rays promptly after the merger, to an early (≈ 1h post-merger) blue kilonova precursor signal, to synchrotron emission years after the merger ('kilonova afterglow'). Despite the fact that fast ejecta components have been seen in a number of numerical relativity simulations, their physical origin has remained unclear. In this talk I will discuss new simulations with the Lagrangian numerical relativity code SPHINCS _BSSN which shed fresh light on the ejection mechanism(s) and I will discuss potential implications of such fast ejecta.